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Effect of dispersion hardening process on change of R_m tensile strength of EN AC-46000 alloy

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Abstract

Heat treatment of aluminum alloys is performed mainly to increase mechanical properties of the alloys. Very important issue, from improvement of mechanical properties point of view as well as economical aspects of performed treatment, is selection of a suitable parameters of solutioning and ageing operations. The paper presents results of the investigations concerning effect of the performed heat treatment on change of tensile strength of the EN AC-46000 (AlSi9Cu3) alloy. Investigated alloy was melted in electric resistance furnace. Run of crystallization is presented with making use of the thermal derivative method (ATD). This method was also implemented to determination of heat treatments' temperature range of the alloy. Performed heat treatment resulted in growth of the R_m tensile strength. Performed tests have enabled determination of temperature and duration of solutioning and ageing operations of the investigated alloy, which would condition obtainment of improved R_m tensile strength. The tests were performed in laboratory conditions.

Keywords: heat treatment, ATD, tensile strenght

1. Introduction

Aluminium–silicon alloys have the potential for excellent castability, good weldability, good thermal conductivity, high strength at elevated temperature and excellent corrosion resistance [1-4].

Usage of these alloys as raw material for casting components of machinery in connected with controlling of morphology of silicon precipitations through thermal changes in solid state and/or modification of the alloy [5-10].

The structure and properties of these alloys are very much dependent on the cooling rate, composition, modification and heat treatment operations.

Heat treatment of aluminum alloys, aimed at increase of their strength mainly, consists in dispersion hardening (of precipitation type), i.e. in successive carrying out of solutioning and ageing operations of the solid solution. The main condition, constituting the base to precipitation hardening of alloys is reduction, together with decrease of temperature, of boundary solubility of alloying constituents in solid state [2,3].

Precipitation of dissolved constituent from supersaturated solution α, during cooling down, leads to change of properties of the alloy. Precipitation of the phase from supersaturated solid solution is obtained through annealing in temperature, in which solid solution constitutes equilibrium structure, and next cooling down to lower temperature, in which solid solution is metastable and mixture of two phases creates the stable structure. In silumins containing magnesium or copper only, precipitation hardening is obtained in result of precipitation of the Mg_2Si, Al_2CuMg and Al_2Cu phases, in process of ageing after previous solutioning [3].

Economical aspect, connected with long lasting thermal processes, constitutes very important issue connected with

processes of heat treatment of silumins, and therefore, in this case optimization of solutioning and ageing parameters has the prime meaning.

Implementation of registration methods of crystallization processes (ATD, ATND) enables determination of quality of the alloy [2, 11-16], and enables determination of temperature ranges of solutioning and ageing treatments, basing on analysis of recorded curves [17]. It is especially important, taking into consideration a fact of necessity of assurance of suitable material structure – destined for heat treated castings – and being characterized by dispersanted precipitations of eutectic silicon, which facilitate processes of its coagulation and coalescence [18].

2. Methodology of the research

The EN AC-AlSi9Cu3 alloy is characterized by very good casting and technological properties. Due to very good mechanical properties, this alloy is used for heavy duty components of machinery, like cylinder heads and pistons of engines.

The first stage of the investigations consisted in testing of the crystallization course for the alloy from pig sows.

Next, one performed treatment of refining with use of Rafal 1 preparation in quantity of 0,4% mass of metallic charge. After completion of the refining one removed oxides and slag from metal-level and performed operation of modification of the alloy with strontium, making use of AlSr10 master alloy in quantity of 0,5% mass of metallic charge (0,05% Sr).

Test pieces to strength tests were prepared according to PN-88/H-88002 standard, whereas static strength tests were performed on ZD-20 tester.

Process of solidification and melting of the alloy was recorded with use fully automated Crystaldimat analyzer.

Chemical constitution of the investigated alloy is presented in the Table 1. Analysis of chemical constitution was performed with use of spectrometric method (GDS 850A type emission spectrometer with glow-type excitation).

Table. 1 Chemical constitution of investigated alloy

EN AC-46000	Si	Fe	Cu	Zn	Ti	Mn	Ni	Sr	Pb	Cr	Mg	Al.
	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
from pig sows	7,88	0,6	4,5	0,658	0,12	0,138	0,33	-	0,06	0,04	0,4	rest
refined	8	0,75	3,8	0,65	0,17	0,206	0,5	-	0,05	0,08	0,327	rest
modified	8,5	0,65	4	0,6	0,18	0,15	0,32	0,035	0,05	0,07	0,3	rest

In the Fig. 1 are shown recorded curves of heating (melting) and crystallization of refined and modified alloy, recorded with use of the ATD method.

On the thermal curve were marked temperatures of solutioning and ageing treatments of the investigated alloy.

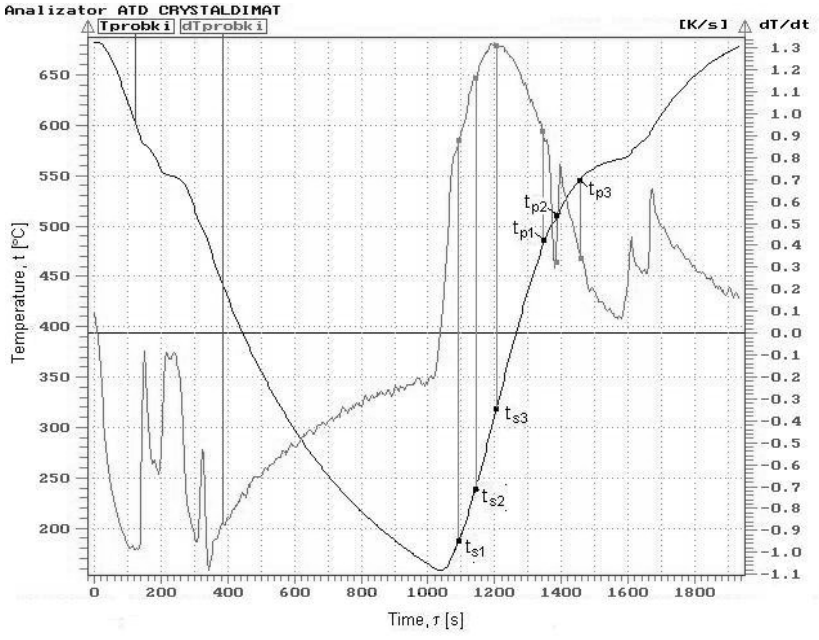

Fig. 1. Curves of the ATD method for refined and modified EN AC-46000 alloy

In the Table 1 are presented parameters of the heat treatment operations for tristage plan of testing with four variables. For the assumed plan of the investigations, number of configurations amounts to 27.

Table. 1. Heat treatment parameters of the alloy

solutioning temperature t_p [^oC]	solutioning duration τ_p [h]	ageing temperature t_s [^oC]	ageing duration τ_s [h]
t_{p1} - 180	0,5	t_{s1} - 525	0,5
t_{p2} - 250	1,5	t_{s1} - 540	1,5
t_{p3} - 330	3	t_{s1} - 555	3

Temperatures of solutioning and ageing treatment were selected on base of recorded points values from the ATD melting curves (Fig.1).

3. Description of obtained results

Tensile strength obtained for the raw alloy (from pig sows) amounted from 213 to 243 MPa. After refining there occurred a slight change of the R_m tensile strength (246-249 MPa). Performed operation of modification of the alloy enabled obtainment of the R_m tensile strength within range of 248-272 MPa.

Obtained results show at distinct growth of strength of the alloy after refining and modification, comparing with mechanical properties of raw alloy (from pig sows) and refined alloy.

To the heat treatment one used refined and modified alloy.
In the Fig. 2 are shown average values of the R_m tensile strength for the EN AC-46000 alloy after the heat treatment, with respect to values obtained in case of the alloy without the heat treatment.

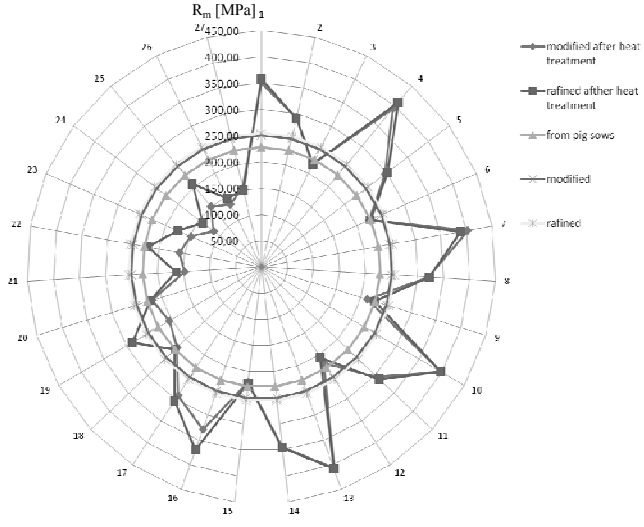

Fig. 2. Change of R_m tesile strength of the investigated alloy for individual configurations of the testing plan

Modification treatment of the alloy did not effect in any significant changes in R_m tensile strength of the investigated alloy after the heat treatment, with respect to refined alloy which underwent the same treatment (Fig. 2).

In the Figs. 3-4 are presented spatial diagrams of influence of temperatures and durations of solutioning and ageing treatments on change of the R_m tensile strength of the investigated alloy.

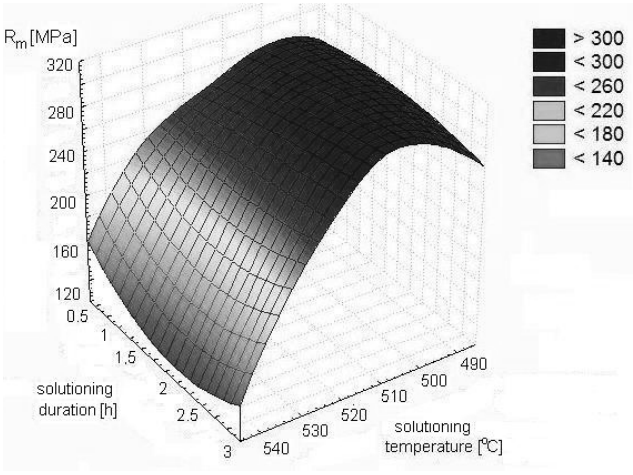

Fig. 3. Effect of temperature and duration of solutioning on R_m tensile strength of the EN AC-46000 alloy

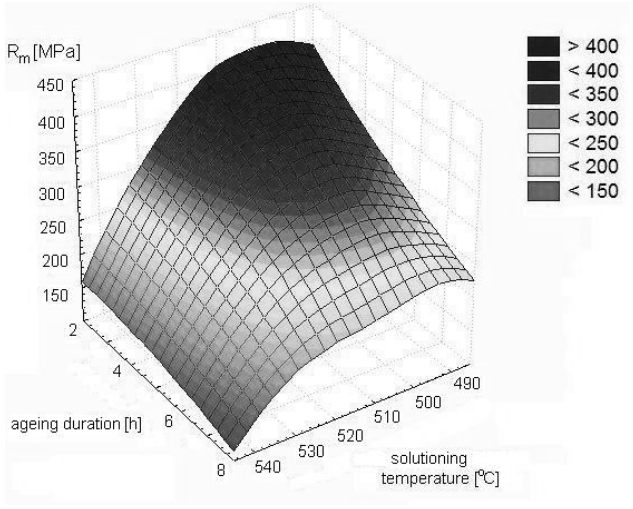

Fig. 4. Effect of temperature solutioning and duration ageing on R_m tensile strength of the EN AC-46000 alloy

Making comparison of the obtained average values of parameters from the test of the alloy after heat treatment and the alloy without heat treatment, one confirmed growth of the R_m tensile strength with 65%.

For the specified parameters (4,7,10,13 – Fig. 2) of the heat treatment there were obtained the best (maximal) mechanical properties of the alloy.

4. Conclusions

On base of the test results one should confirm that heat treatment of the EN AC-46000 effects in growth of its R_m tensile strength.

Usage of the ATD method has enabled preliminary determination of temperature ranges of solutioning and ageing treatments of the investigated alloy.

The highest R_m tensile strength, amounted to 407 MPa, was obtained for the following parameters of the heat treatment operations:

a) solutioning temperature - 510 ^oC,
b) solutioning duration - 1,5 hour,
c) ageing temperature - 240 ^oC,
d) ageing duration - 2 hours.

Selection of suitable parameters of solutioning and ageing treatments constitutes necessary condition to obtainment of positive effects of the heat treatment in form of growth of mechanical parameters of the alloy.

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